ELSEVIER
Available online at www.sciencedirect.com
SciVerse ScienceDirect
Procedia Engineering 48 (2012) 520 – 524
Procedia Engineering
www.elsevier.com/locate/procedia

MMaMS 2012

Influence of fly ash content in cement paste on size of creep

Pavel Padevět[a]*, Petr Bittnar[a]

[a]*Czech Technical University, Faculty of Civil Engineering, Thakurova 7, Prague 6, 166 29, Czech Republic*

Abstract

The cement paste is basic part of concrete and can contain a various additives. Fly ash is one of the materials useable as an admixture in the cement paste and concrete. The changes of properties of the cement paste mixed with fly ash were observed during several months. Creep of dried and saturated cement paste was measured for one complete month. The preparation of the cement paste and specimens is described in paper, too. From tests were obtaining two different kinds of data, about water dried and saturated specimens. *The measured data was evaluated and compared with results of computational model with a creep model B3.*

Keywords: Cement paste; Basic creep; Fly ash; Shrinkage;

1. Fly ash like the waste material

1.1. Why fly ash?

The power plants produce annually 8 million tons of fly ash in the Czech Republic. In the Czech Republic is the year production of the fly ash 2.5 times higher than production of the cement. Even more interesting is the annual amount of concrete, which is close to the 6 million m^3. These factors are interesting for use the fly ash in the production of the concrete or cement. Fly ash is generated as the secondary product by burning brown coal in the lignite power plants.

1.2. Properties of the fly ash

The generated quantity of the fly ash is between 10 % and 30 % of the original volume of burned coal. Grain size fly ash from power plants is between 1 and 1000 microns [1]. Density of ash from power plants is between 750 and 950 kg/m^3. From the perspective of chemistry, the fly ash is inert material; the main component is SiO_2 and $Al2O_3$ and CaO and SO_4. The fly ash is a suitable building material for their inert behavior.

Conventional fly-ash contains up to 80 % glass phase, as the main component. Sulfur content (expressed as SO_3) usually does not exceed 1 %. In the high-temperature combustion of coal is not necessary to add ground limestone into burnt mixture. The resulting ash typically does not contain calcium compounds such as $CaSO_4$, and also higher amount of sulfur in the form of SO_3. The combination of cement paste and fly-ash from power plants creates an interesting productivity,

* Corresponding author. Tel.: +420-224-354-484; fax: +420-224-310-775.
E-mail address: pavel.padevet@fsv.cvut.cz.

doi:10.1016/j.proeng.2012.09.548

which has its advantages, but also its weaknesses. Among the positive properties can be conceived: a higher resistance to aggressive environments, lower density and improved workability.

Among the negatives can to include decreased compressive strength and the potential increased content of heavy metals that are contained in the ash. The strength of concrete [2], [3] is also possible improve in case of using of the fly ash by their activating in concrete. Fly ash is contained in many types of cement as an additive. Activation of fly ash can be started, appropriately CaO content in cement, which are often very complicated.

In several previous works have been defining the characteristics of cement paste mixed with ash from power plants [4]. Tensile bending strength of cement paste with addition of fly ash reaches higher values than the pure cement paste. Modulus of elasticity of the final mixed material is lower [5]. Fracture energy [9] of cement paste with fly ash also decreases, but this decrease is not so significant [6]. Very good values of tensile strength in bending were achieved when the weight ratio of cements and fly ash was 1:1.

2. Cement paste with fly ash

In this work the fly ash was used like the filler in the prepared cement paste. Its production was based on the high-temperature combustion of brown coal. The experiments were realized by the cement paste with addition of the conventional fly ash. The components of cement paste were: Portland cement CEM I 42.5 R, fly ash and water [10]. The method of preparation consists in mixing the dry ingredients of the mixture and then mixing with water. From components were prepared the cylindrical specimens into the plastic moulds. Water / cement – fly ash ratio of the prepared cement paste was 0.4. In the cement paste was used 40 % water of the weight of solid components. Content of the fly ash was defined in weight of cement part. In this study was used 60 % of weight of cement and 40 % of weight of the fly ash. The specimens were taking out from moulds one day after production. The surface of the specimens with fly ash is little bit more porous than surface of the pure cement paste. After that the specimens were placed into the water basin.

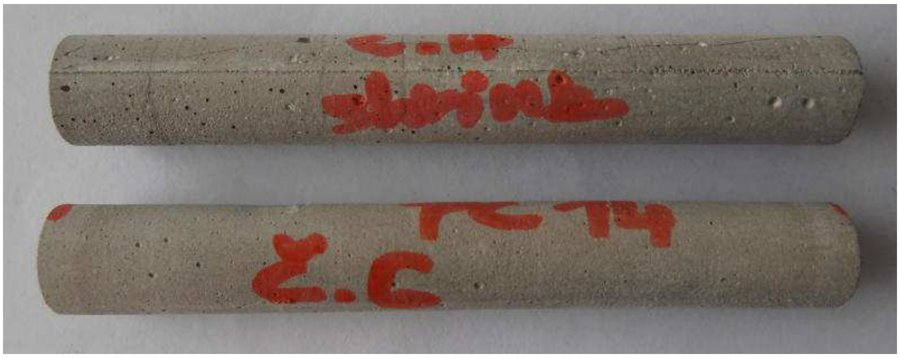


Fig. 1. Specimens for the shrinkage test (upper) and for creep test (lower).

The specimens were cut shorted on the length 70 mm (Fig.1). A diameter of prepared cylinders was 10 mm. For the experiments were prepared six specimens. First two specimens were determined for a measurement of creep in drying condition. Other two specimens were used for a measurement of shrinkage. The last two specimens were used for a measurement of creep in water saturated condition (Table 1).

The specimens were placed in water basin for five month.

3. Testing of specimens

To test begin by material properties obtained from tests of similar materials based on cement and fly ash. The strength of material is important for the definition of size of the loading. Applied load corresponds to the size of the loading in the elastic behavior of the cement paste.

The age at the beginning of the testing specimens was 120 days. The measurement of creep was realized in the lever mechanisms. The total number of specimens was six of which two specimens were tested on shrinkage, only. The other two specimens were tested in water saturated condition and the last two specimens in water dried condition. Applied load on specimen achieved size between 691 and 697 N. This force was unchangeable during process of measurement. All specimens were covered in the foil due to guarantee condition of the humidity. Dry solids were prepared in the drying oven one day at temperature 105°C. The saturation of specimens by water was ensured by their dipping into water. The specimens were loaded by a plumbs after their placing in the lever mechanisms. For example see Figure 2, where loading is show in increasing curve of the creep at deformation 56μm (relative value of deformation is 0.8).

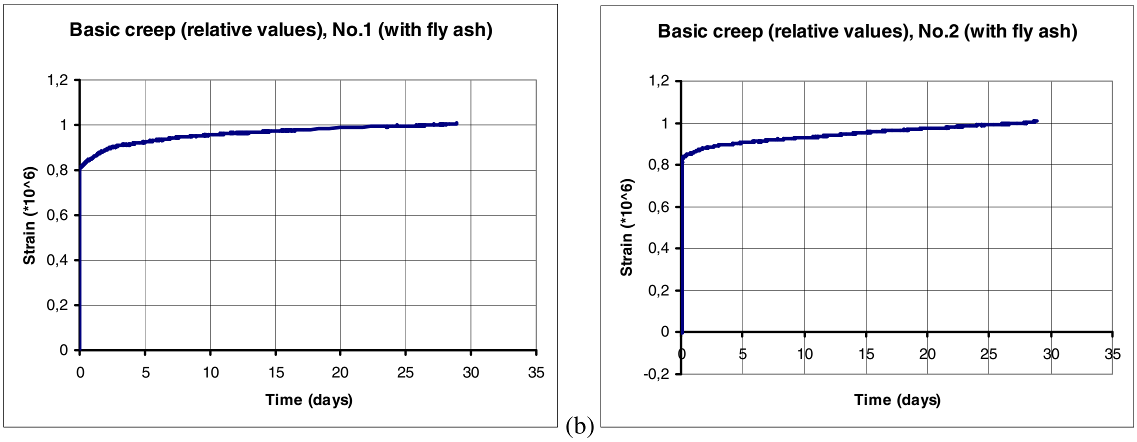
Table 1. Volume weight before testing.

Specimen number	Condition	Volume density (kg/m^3)
1	Dried	1538
2	Dried	1572
3	Dried	1600
4	Dried	1619
5	Water saturated	1935
6	Water saturated	1979

4. Testing of specimens

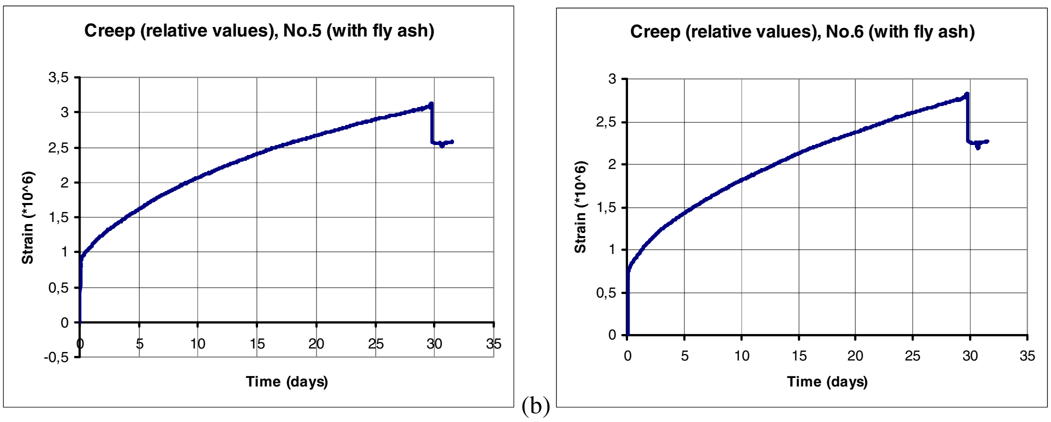
After the finishing tests the change of weight was check for observe of the transport of water. The change of weight was to 1 % and humidity conditions were maintained.

Next graphs (Fig. 2 and 3) display results of creep tests. Figure 2 display relative values of the basic creep of cement paste. The basic creep of cement paste was calculated like difference between creep and shrinkage of the specimens. The increasing of the deformation of specimen No.1 is 15 μm and deformation of specimens No. 2 is 23 μm after 29 days.



(a) (b)

Fig. 2. Basic creep of water dried specimens (a) No.1 and (b) No.2.



(a) (b)

Fig. 3. Creep of water saturated specimens (a) No.5 and (b) No.6

Figure 3 display relative values of creep of the water saturated specimens. Deformations were calculated in the same way as in the first case. The increasing of the deformation of specimen No.5 is 155 µm and deformation of specimens No. 6 is 145 µm after 29 days. In figure 3 is possible see unloading after 29 days and short increasing of creep of the specimens without loads.

5. Simulation of creep tests

At figures 4 and 5 are displayed results of comparison between curves of creep and simulation of creep. The curves of basic creep are displayed in the figure 4. The curves of creep of specimens saturated of water are displayed in the figure 5. The simulations of creep were solved in OOFEM program [7]. It is the programming environments with built/in model B3 for creep [8].

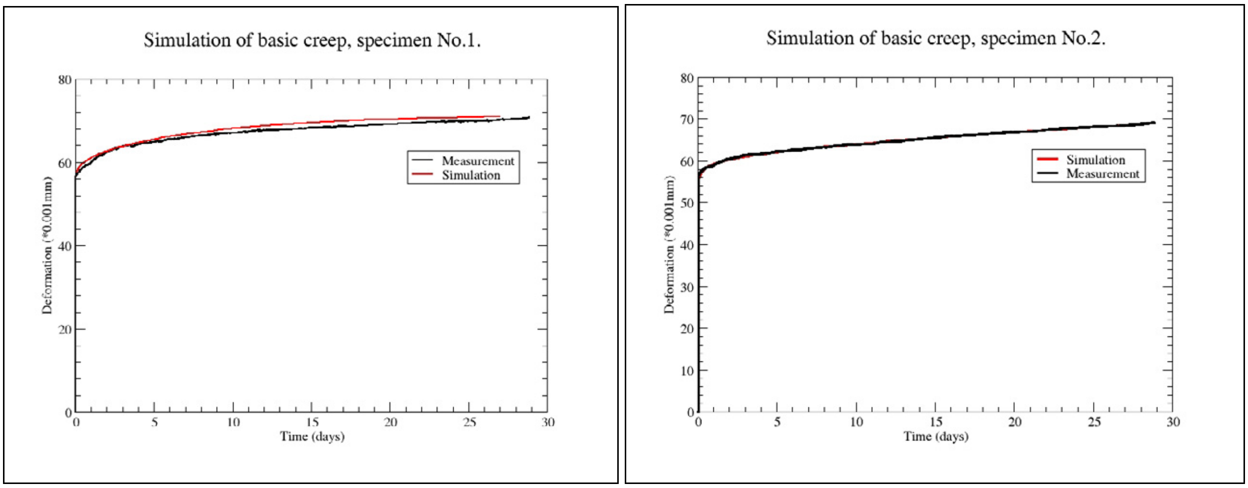


Fig. 4.Simulation of the basic creep of water dried specimens (a) No.1 and (b) No.2.

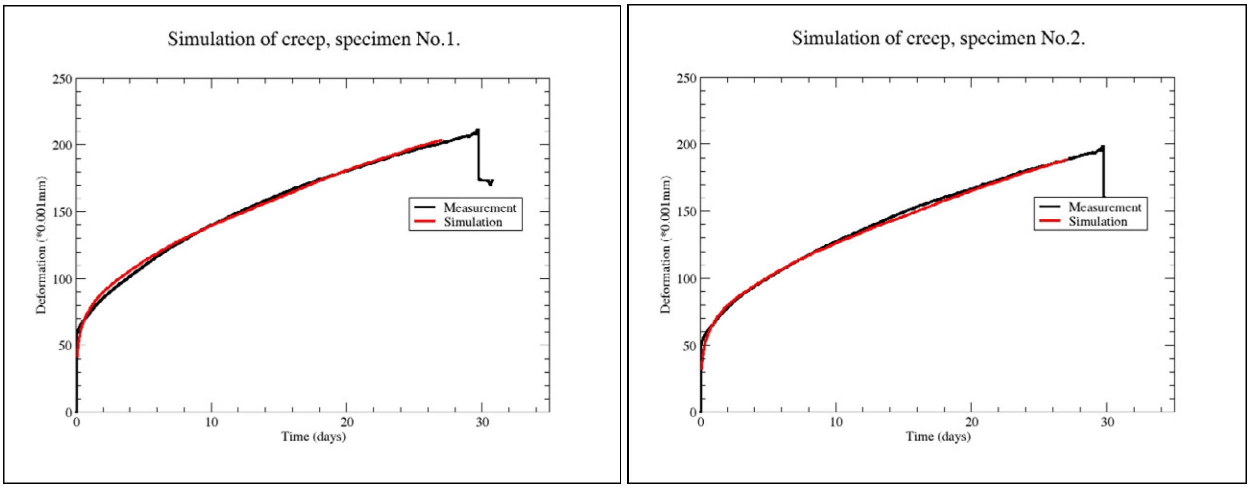


Fig. 5. Simulation of the creep of water saturated specimens (a) No.5 and (b) No.6.

Very good agreement was reached in the case water dried and saturated specimens. In the simulation of creep by B3 model is important right choice of selection of the essential coefficients q_1 to q_4. In the table 2 are displayed selected coefficients q which affects the shape of curve of the creep.

Table 2. Coefficients q for B3 model of creep.

Specimen number	q_1	q_2	q_3	q_4
1	0.081262	-100.54	9.1978	-0.34482
2	0.070090	-1.116827	0.139287	0.038830
5	-0.13502	-100.48496	9.53563	0.31785
6	-0.170419	3.404279	0.087555	0.662869

6. Conclusions

The presented graphs show, the basic creep reach in relative value over 29 days to 0.19 (it is average value 19 microns). Nearly identical results are obtained using the curves of shrinkage of specimen No. 3 and No.4.

The water-saturated specimens [8], reaches very high values creeping. The relative value of the creep of water saturated cement paste without the influence of shrinkage after 29 days reached average value to 2,155 (it is average value150 microns). The base for computing of the relative values was length of the specimens 70 mm. All specimens were tested in the age four months. The age of the production has a significant influence on the size of creeping at the initial stage of measurement. In all cases, measurements of deformation solids, the increase was steepest during the first 5 days.

In the past, compliance tests were conducted simulations of creep of pure cement paste model B3 [9]. Even if the simulation creeping of cement paste mixed with fly ash is possible to achieve good agreement between the model and real measurements. Table 2 contains the overview of selected factors creeping q.

Acknowledgements

This work has been supported by project GACR under No. P104/11/2285.

References

[1] http://www.cez.cz/cs/odpovedna-firma/zivotni-prostredi/programy-snizovani-zateze-zp/vyuziti-vedlejsich-produktu-uhelnych-elektraren.html, Information about secondary energy products.

[2] Neville, A. M., 1997. *Properties of Concrete*, John Wiley & Sons, ISBN 0-470-23527-6.

[3] Polák, M., Plachý, T., 2010. Long-Time Monitoring of Thermal Action on a Prestressed Concrete Bridge Structure, in *Proceedings of the 48th International Scientific Conference on Experimental Stress Analysis* ,Velké Losiny, May – June 2010, pp. 369-376, ISBN 978-80-244-2533-7.

[4] Padevět, P., Bittner, P., 2009. "Measuring of Creep of Cement Paste Specimen", *Proceedings of the 2nd WSEAS International Conference on Applied Mathematics, Simulation, Modeling (ASM'09),* Athens, Greece, 2009, pp. 33-39.

[5] Mezerová, L, Kuklík, P., 2010. "Variability of Strength for Beams from the Blues Laminated Tiber", in *Proceedings of the 48th International Scientific Conference on Experimental Stress Analysis* ,Velké Losiny, May – June 2010, pp. 257-260, ISBN 978-80-244-2533-7.

[6] Zobal, O., Padevět, P., 2011. Compressive strength and the tensile strength in bending after 28 days, *Proceedings of the Conference Nano and Macro Mechanics 2011*, Prague, ISBN 978-80-01-04892-4.

[7] Patzák, B., 2000. OOFEM project home page, http://www.oofem.org.

[8] Bažant, Z. P., Baweja, S., 1995. Creep and Shrinkage Prediction Model for Analysis and Design of Concrete Structure – Model B3, *Materials and Structures,* Vol. 28, pp. 357-365.

[9] Van Mier, J. G. M., 1997. *Fracture Processes of Concrete* CRC Press, ISBN 0-8493-9123-7.

[10] Padevět, P., Zobal, O., 2010. Change of Material Properties of the Cement Paste CEM I, in *Proceedings of the 48th International Scientific Conference on Experimental Stress Analysis,* Velké Losiny, May – June 2010, pp. 307-310, ISBN 978-80-244-2533-7.